Interim Report

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ANALOG TO DIGITAL CONVERSION AND PROCESSING OF MSS DATA USING A HYBRID COMPUTER

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Resource Inventory, Land Use, and Pollution

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The objective of this investigation was to design and implement a process for the conversion of multispectral scanner data from FM magnetic tape recordings to digital magnetic tape recordings of a previously defined format. Specifically, the problem was to design a system which will directly accept analog data from FM magnetic tape recordings produced by the Bendix eight-channel multispectral scanner, sample the analog data, convert those samples to digital numbers, arrange those digital values into standard ORSER format, and output the data onto digital magnetic tape in standard IBM System 360 nine track tape mode of 32 bit words written in 800 bits-per-inch density. The design was further restricted to implementation on existing systems available to ORSER. It also was required that the multispectral scanner and the conversion system maintain a high degree of accuracy in the measurement and sampling of the spectral response of the subject. Thus, simultaneous sampling is considered advantageous over simple multiplexing in which each channel is sampled as it is input to the analog-to-digital converter, no two channels ever being sampled at the same instant.

The system used for implementation was the hybrid computer operated by the Hybrid Computer Laboratory of The Pennsylvania State University. The hybrid computer consists of a Digital Equipment Corporation PDP-10 digital computer and an EAI 680 analog computer mated by a special interface unit to translate data and control signals from one computer to the other. The sampling and conversion of the multispectral scanner data is controlled by a digital program. The maximum sampling speed is limited by hardware speed, including not only the maximum speed (31,700 samples per second) of the converter, but also the instruction execution speed of the controlling digital computer. Prior to this project, the maximum sampling speed available was limited by existing subroutines to approximately 11,000 samples per second. For the Bendix data, a theoretical minimum rate of 10,000 samples per second was required.

Normally, up to five times the minimum sampling rate is used for convenient interpretation. Thus, up to 50,000 samples per second could be used. The 11,000 samples per second is therefore an undesirably limited maximum sampling rate when the hardware is theoretically capable of a maximum of 31,700 samples per second.

A new subroutine was developed so that data rates approaching the hardware maximum might be achieved. The sampling periods and rates obtained with the special subroutine depend upon the number of channels sampled and that part of core in which the program is located. However, the sampling rates for eight channels of data were increased to 19,544 samples per second (2443 samples per second per channel) in fast core and 17,496 (2187) in slow core. This is an obvious improvement over the previous maximum of approximately 11,000 samples per second.

Besides the higher speed, there are other features in the new subroutine designed for the specific application of multispectral scanner data conversion. One such feature affects simultaneous sampling of all channels. Also, the time between samples may be fixed (constant) for all samples, or an adaptive sampling rate, such as that required to geometrically correct multispectral scanner distortions, may be utilized. Once the multispectral data is converted into raw, digital numbers, it must undergo another conversion into the specified ORSER format before it is ready for storage on magnetic tape. There are three operations in this conversion. The first operation involves both a scale change and an axis translation. The second operation, of rearranging, not only fits the data to the required format but also reverses the order of the samples, so that maps made from the output have the standard point of view (that of looking down from above as if in an aircraft) instead of the mirror image (as if looking up at the earth's surface from below), as would happen if no change were made. The third operation reduces the data storage requirement by a factor of four, by packing four consecutive 8-bit words into one 32-bit word. Another subroutine improved the speed of writing onto magnetic tape by at least a factor of four over the existing magnetic tape subroutine. In addition, both of the new subroutines offer the programmer more flexibility than their predecessors as a result of their simplicity.

The advantages of the conversion system developed in this investigation over a simple bulk digitizing system are five-fold. First, more precise control of the sampling of the analog signals by the hybrid system fits the data into the coordinate system more accurately than does simple digitizing. Second, the final product of the hybrid system can be written in the format required by any user system instead of a single format particular to the digitizing system. Third, the conversion system requires no specialized equipment for implementation; it is strictly a software system which could be easily altered to new specifications without equipment changes. Fourth, the hybrid implementation allows geometric corrections to be performed on the MSS data as it is being sampled. Fifth, the analog computer provides preprocessing of the data before conversion.

Upon completion of the conversion system implementation, the system was used to convert the analog data from 13 flightlines flown on 5 May 1971 by Bendix Corporation. The data was originally recorded on one-inch-wide magnetic tape at 60 ips with an Ampex FR 1600, 14-track wideband FM tape recorder that has a cutoff frequency of 200 kHz at that speed. Due to the unavailability of a comparable tape playback unit for use in the Hybrid Computer Laboratory, the data was rerecorded onto half-inch-wide magnetic tape with an Ampex FR 1300, seven-track FM tape recorder at the Bendix ground station in Ann Arbor, Michigan. At the same speed, 60 ips, the FR 1300 has an upper cutoff frequency of 20 kHz.

The Bendix scanner senses eight spectral bands. The eight analog signals plus a synchronization signal fit easily on the 14-track recorder, but there are two signals too many for the available seven-track unit. To resolve this problem, two seven-track tapes were made from the original 14-track recording, each containing only six data channels and the synchronization channel. The four data channels estimated to contain the most information appear on both tapes. These analog tapes were converted to digital data and then merged on the IBM 360 at The Pennsylvania State University Computation Center. For verification purposes, a comparison for each flightline was made between the imagery produced on a film recorder from the original flight tape and the computer-generated reflectance map of the same flightline and channel, produced from the digitized rerecorded data.

The limit of computational efficiency was observed during the digitizing runs. It was determined that the new digitizing system results in an average of 2.75 percent of the computer time spent waiting for the next scan line, i.e., the system resulted in 97.25 percent efficient use of the computer while the program is in the digitizing phase.

There are a number of extensions of this investigation that could prove useful. The preprocessing of analog data prior to sampling and conversion could be treated as a feature extraction problem. The concept of non-linear sampling to compensate for scanner geometry could be carried further by using actual terrain contour information instead of assuming the terrain to be flat.

As discussed above, the immediate objective of this work was to digitize the Bendix data. This data was collected over central Pennsylvania and will serve as a source of ground truth for high altitude aircraft and satellite studies, as well as a direct source of information in itself. The conversion system which was developed is suitable for digitizing other aircraft data. Discussions have been held with Johnson Spacecraft Center personnel regarding the possibility of digitizing some data collected on the supporting C130 aircraft program.

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